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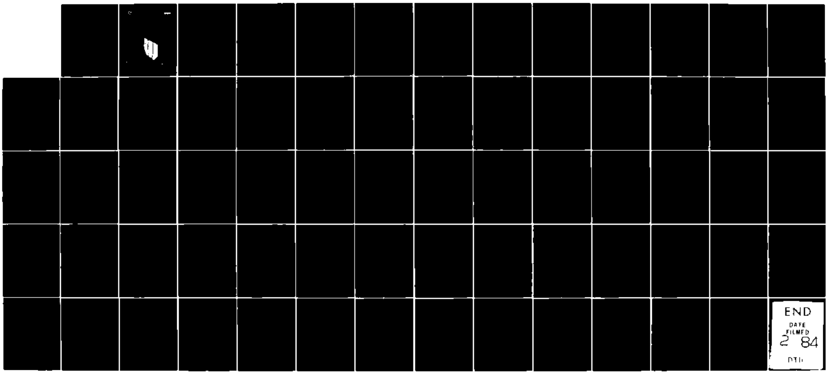

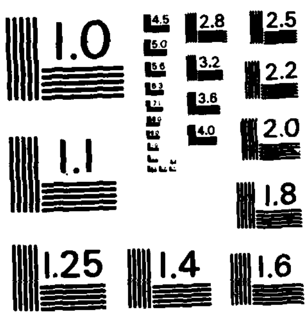

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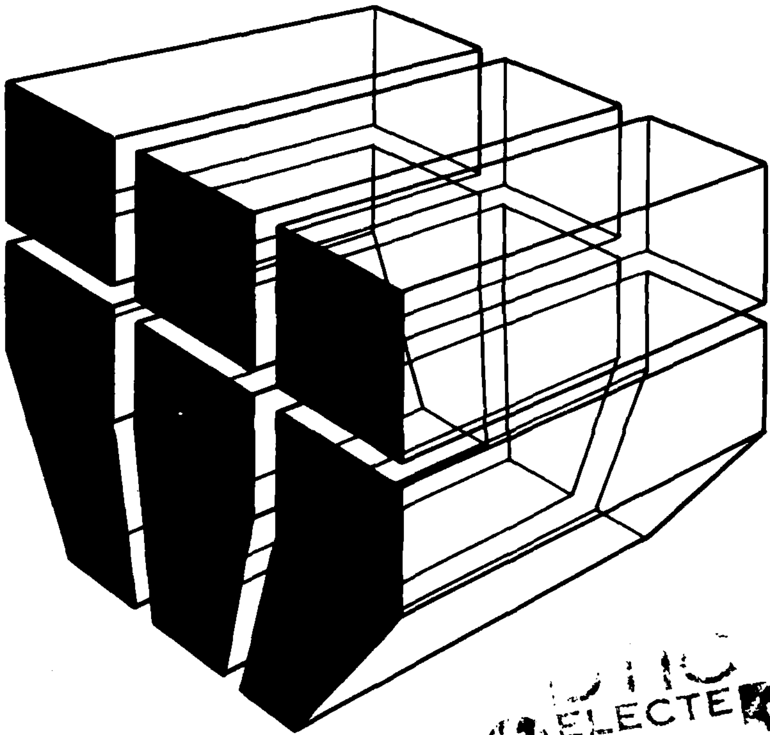
US Army Corps
of Engineers
Construction Engineering
Research Laboratory

Technical Report N-168
December 1983

SOLVENT "CRADLE-TO-GRAVE" MANAGEMENT GUIDELINES FOR USE AT ARMY INSTALLATIONS

by
B. A. Donahue
M. B. Carmer



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Establishment of "cradle-to-grave" guidelines for procurement, use, and disposal of solvents at installations is one way the Army can manage and control hazardous materials. This report presents information derived from a literature review and installation site visits; this information has been used to develop a Solvents Management Plan. This plan provides Army personnel with guidelines on minimizing solvent use; substituting less toxic solvents; minimizing solvent wastes; proper handling, storing, and disposal of solvent wastes; and recycling of solvent wastes.

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FOREWORD

This investigation was conducted for the Assistant Chief of Engineers under Project 4A76270A896, "Environmental Quality for Construction and Operation for Military Facilities"; Task Area A, "Installation Environmental Management Strategy"; Work Unit 032, "Hazardous/Toxic Waste Control." The research was performed by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL). V. J. Ciccone & Associates, Inc., Woodbridge, VA, prepared the technical report under Contract Number DACA88-82-M-0580. The CERL Principal Investigator was Mr. B. A. Donahue. The Technical Monitor was Ms M. Read, DAEN-ZCF-U.

Dr. R. K. Jain is Chief of EN. COL Paul J. Theuer is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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FOR USE AT ARMY INSTALLATIONS

1 INTRODUCTION

Background

Recent national legislation and regulatory actions, such as the Resource Conservation and Recovery Act (RCRA), have emphasized that hazardous materials use and disposal is a nationwide problem. The Army uses large quantities of hazardous materials in many installation activities and has published Army Regulation (AR) 200-1, which specifically addresses the management of hazardous and toxic materials.[1] Other guidance pertaining to solvents is the DOD Consolidated Guidance--Hazardous Material/Hazardous Waste/Disposal[2] and a draft of AR 420-47.[3]

Solvents comprise a broad category of toxic organic chemicals. Organic solvents (those made of carbon, hydrogen, and oxygen) dissolve other substances and form a uniformly dispersed solution. They are a concern because they are toxic and sometimes ignitable.

Organic solvents encompass a wide range of compounds, including aromatic or aliphatic hydrocarbons, esters, ketones, amines, and chlorinated or fluorinated hydrocarbons. These chemicals have many uses, such as coatings (paints, varnishes and lacquers), industrial cleaners and degreasers, printing inks, and dry cleaning fluids. It is outside the scope of this study to list each solvent used by the Army; however, the following list provides a basic description of classes of solvents and commonly used examples of each type:

1. Hydrocarbon solvents--hydrogen and carbon compounds derived from coal tar or petroleum:

   Xylene
   Naptha
   Aromatic naptha
   Dry cleaning solvent (Stoddard Solvent; PD-680)
   Mineral spirits (Varsol)
   Hexane
   Heptane

---

[1] Environmental Protection and Enhancement, Army Regulation (AR) 200-1 (Department of the Army, November 1980).
[2] DOD Consolidated Guidance--Hazardous Material/Hazardous Waste Disposal (Department of Defense [DOD], April 1981).
[3] Solid and Hazardous Waste Management, AR 420-47 (Department of the Army, [in publication]).

2. Halogenated solvents--hydrogen, carbon, and halogen compounds; the halogen is generally fluorine or chlorine. These are mostly man-made compounds:

- 1,1,1-Trichloroethane
- Trichloroethylene
- Trichloroethane
- Trichloromethane
- Methylenechloride
- Freon

3. Oxygenated solvents--hydrogen, carbon, and oxygen compounds:

- Ketones (acetone, methyl ethyl ketone [MEK], methyl isobutyl ketone [MIBK])
- Alcohols (ethanol, methanol, butanol, propanol)
- Esters (ethyl acetate, butyl acetate)
- Ethers (diethyl ether)
- Ethylene glycol

4. Mixtures--combinations of two or more solvents, or a solvent and other organic compound:

- Paint thinners
- Lacquer thinners
- Lithographic solvents.

Organic solvents have a wide variety of commercial and industrial uses which fall into three major areas: cleaners, diluents, and test fluids. Cleaning solvents include degreasing compounds for automotive and equipment parts, spot removers for fabrics, dry cleaning solvents, and corrosion-removing compounds. Diluents are used as liquifiers or dissolvers, and include the alcohols, ketones, and esters, as well as thinners for paints and lacquers. Test fluids include heptanes and freon; an example of their use is for instrument calibration.

The U.S. Army Construction Engineering Research Laboratory (CERL) has been investigating the use of toxic materials on Army installations and better methods for their management and ultimate disposal. The large quantities (millions of gallons) of solvents used in maintenance and equipment refurbishing operations and disposed of Army-wide are a major concern. Solvent use is common on all installations throughout the continental United States and overseas. Reducing solvent hazards requires consistent managerial and technical guidance for use at all Army installations. Such guidance would include outlining procedures for solvent use minimization, substitution of less toxic solvents whenever applicable, waste solvent minimization, waste solvent handling, waste solvent storage, waste solvent reuse/recycling, and waste solvent disposal.

Objective

The objective of this study was to develop an Army "cradle-to-grave" Solvents Management Plan for use at Army installations.

Approach

A literature search was conducted to obtain documents with information pertaining to solvents and hazardous materials management. Selected Army installations were visited to gather information about current procurement, use, control, and disposal of solvents. Current solvents management techniques were discussed with other Army and Department of Defense (DOD) agencies, and types and quantities of solvents procured by Army installations were identified. Next, current manufacturers' information and product literature on solvent recovery/reclamation equipment were gathered, and solvent reclamation centers and practices were identified. Using the information gathered from these sources, an Army "cradle-to-grave" Solvents Management Plan was developed.

Mode of Technology Transfer

It is anticipated that the guidelines presented here will impact future updates of AR 200-1, Environmental Quality, Environmental Protection and Enhancement, and AR 420-47, Facilities Engineering Solid and Hazardous Waste Management. These guidelines present several new approaches to solvents management within the Army; however, they are purposely general in nature in order to be applicable to the broadest category of Army users. Appendix B--an economic analysis for solvent management options--could be published as an ETN. Toxic waste management actions taken by the Department of Defense, the Department of the Army, and the Defense Logistics Agency (DLA) will also impact these guidelines.

2 SOLVENT INFORMATION REVIEW

Literature Search

An extensive search identified literature on solvent use, management, and disposal within both Government and private industry. Information from a variety of sources was reviewed for relevance to Army solvents management problems. First, a customized search strategy (see Table 1) was developed to access the Defense Technical Information Center (DTIC) database. This strategy addressed the following subjects: solvents management, solvents recovery, solvents documentation, solvents containers, solvents disposal, and oily wastes.

Next, microform data files from the Army Retrieval Microform Systems (ARMS) and from the Coast Guard Chemical Hazards Response Information System (CHRIS) were reviewed. Data listings from both the U.S. Army Corps of Engineers' Environmental Technical Information System (ETIS) and CERL's Hazardous Materials Management System (HMMS) were also reviewed for the approximately 800 organic solvents known to be used.

Current Federal and State laws, U.S. Environmental Protection Agency regulations, and U.S. Army regulations on the handling and disposal of various materials classified as hazardous were reviewed. Also, various types of contract solvent reclaiming plants were investigated.

Summaries of 388 reports were identified from DTIC and screened for relevance; documents judged to be pertinent were ordered for detailed review. Documents retrieved from other sources included the major efforts in solvents management conducted by the Exxon Research and Engineering Company for the Naval Facilities Engineering Command, and by Navy staff for the Naval Air Systems Command.

Applicable Army regulations, manuals, and publications were reviewed, as were Federal laws and regulations on hazardous materials storage, use, treatment, and disposal.

The uncited references list the documents reviewed that are pertinent to this study. A discussion of significant findings follows.

The annual U.S. production of solvents exceeds 900 million gal. The 1980 U.S. production of 1,1,1-trichloroethane was more than 20.5 million gal. DOD is a major user of solvents and has funded several previous studies aimed at better management, use, and disposal of contaminated solvents.

Studies conducted by Exxon Research and Engineering Company for the Naval Facilities Engineering Command examined the handling, disposal, and recycling options for solvents and other organic chemicals at Navy and Marine Corps facilities. Part of this work was the development of a guide for use by Navy personnel in the environmental survey of solvents and other organic chemicals. This survey guideline and checklist was tested at various Naval installations.

Table 1

Solvents Search Strategy

Solvents Management

First-Level Search Terms
- Organic Solvents
- Paint Removers
- Paint Thinners
- Solvents

Second-Level Search Terms
- Absenteeism
- Careers
- Cargo Handling
- Configuration Management
- Contract Administration
- Contract Proposals
- Cradle to Grave
- Crisis Management
- Data Management
- Energy Conservation
- Energy Management
- Environmental Management
- Financial Management
- Grade Structure (Persnl Mgt)
- Handling
- Job Analysis
- Job Statisfaction
- Journeyman Level
- Loading (Handling)
- Logistics Management
- Maintenance Management
- Management
- Management Engineering
- Management Planning & Control
- Manhours
- Manpower
- Manpower Utilization
- Materials Handling
- Participative Management
- Personnel Development
- Personnel Management
- Personnel Retention
- Production Engineering
- Propellant Transfer
- Public Administration
- Records Management
- Research Management
- Retirement (Personnel)
- Stacking
- Systems Management
- Waste Management
- Waste Recycling

Solvents Documentation

First-Level Search Terms
- Organic Solvents
- Paint Removers
- Paint Thinners
- Solvents

Second Level Search Terms
- Abstracts
- Bibliographies
- Books
- Catalogs
- Computer Files
- Computer Program Docmtn
- Diagrams
- Dictionaries
- Directories
- Documents
- Encyclopedias
- Engineering Drawings
- Files (Records)
- Handbooks
- Hard Copy
- Indexes
- Instruction Manuals
- Inventory
- Inevntory Analysis
- Inventory Control
- Literature Surveys
- Manuals
- Mechanical Drawing
- Military Publications
- Newspapers
- Obsolescence Theory
- Patents
- Periodicals
- Phase Diagrams
- Pictures
- Price Index
- Programming Manuals
- Records
- Replacement Theory
- Reports
- Reprints
- Schematic Diagrams
- Scientific Literature
- Textbooks
- Theses
- User Manuals
- Wiring Diagrams

Solvents Containers

First-Level Search Terms
- Organic Solvents
- Paint Removers
- Paint Thinners
- Solvents

Second-Level Search Terms
- Ammunition Containers
- Ampules
- Autoclaves
- Bags
- Ballast Tanks
- Barrels
- Bladders
- Bottles
- Boxes
- Canisters
- Cardboard Boxes
- Containerizing
- Containers
- Crucibles
- Dewar Flasks
- Expulsion Bladders
- Flasks
- Fuel Tanks
- Gas Cylinders
- Humidity Cabinets
- Intravenous Bottles
- Oil Tanks
- Packaging
- Packets
- Packing Materials
- Propellant Tanks
- Self Sealing Fuel Tanks
- Shipping Containers
- Spray Tanks
- Storage
- Storage Tanks
- Swim Bladders
- Tanks (Containe
- Trays
- Water Tanks

Solvents Disposal

First-Level Search Terms
- Organic Solvents
- Paint Removers
- Paint Thinners
- Solvents

Second-Level Search Terms
- Disposal
- Garbage Disposal
- Ocean Waste Disposal
- Sewage Disposal
- Waste Disposal

Solvents Recovery

First-Level Search Terms
- Organic Solvents
- Paint Removers
- Paint Thinners
- Solvents

Second-Level Search Terms
- Reclamation
- Recovery
- Recycled Materials
- Reusable Equipment
- Reuse

Oily Waste

First-Level Search Terms
- Garbage
- Liquid Wastes
- Oil Wastes
- Radioactive Wastes
- Sewage
- Slags
- Wastes
- Gases
- Waste Water
- Wastes
- Wastes (Industrial)
- Wastes (Santy Engring)

Results of the Pearl Harbor shipyard survey showed that about 44,000 gal of various solvents are used yearly; of these, 26,000 gal are disposed of as waste. At the time of the survey, a local firm was contracted to incinerate these waste solvents. The study also examined the economics and feasibility of six different disposal and recycling options, with the results indicating that the practiced disposal method costs about $36,000 per year. By instituting maximum recycling practices, the return to the Navy would be about $132,000 per year. Reclaiming only freon and disposing of the other waste solvents would give a return to the Navy of about $64,000 per year.

A similar survey of Naval activities in the Norfolk, VA, area showed that solvent use for major activities was about 217,000 gal per year, of which 119,000 gal were disposed of as wastes. This study provided guidance to help the activities develop a guide to better handle, dispose of, and/or recycle the solvents. The anticipated return to the Navy by installing a central recovery unit for hydrocarbon and chlorinated solvents was anticipated to be $185,000 per year.

For several years, the Navy has been investigating solvent recycling opportunities at Naval Air Rework Facilities (NARFs). A survey of five NARFs to determine types and quantities of waste materials generated showed that little attempt was made to reclaim or salvage materials, including solvents. Later studies developed waste solvent reclamation programs at NARFs. Results of these studies showed that for five NARFs, more than 1,103,000 gal of "major" solvents are used yearly; 87 percent of those are recoverable or recyclable. By contracting for solvents reclamation through commercial channels, the Navy could save more than $1 million per year in disposal and replacement costs.

The literature review also highlighted the fact that incineration of solvent wastes is widely practiced and is also a reasonably priced disposal method. The U.S. Environmental Protection Agency and the Canadian Environmental Bureau have published reports confirming the feasibility and costs of waste solvents incineration.

Site Visits

Three Army installations were visited to obtain information on current Army methods of solvent procurement, use, and disposal, and to identify actual or potential problems with solvents management. The installations visited were Anniston Army Depot, AL; Fort Eustis, VA; and Fort Bragg, NC.

Key personnel were interviewed about details of the procurement, use, and disposal of solvents at the installation. Investigators also observed several typical installation activities that require use of solvents, including degreasing operations using both vapor and cold solvents aircraft, tank, and locomotive maintenance; motor vehicle maintenance; heavy and light equipment maintenance; small and heavy arms maintenance; helicopter washdown; and a floating maintenance ship at a port facility (Fort Eustis).

To obtain additional information, investigators also visited appropriate personnel in the following offices:

1. Office of the Surgeon General, Headquarters, U.S. Army

2. Environmental Policy Branch, Property Disposal Branch, Property Disposal Section, Defense Supply Agency, DLA

3. Environmental Quality Division, Naval Facilities Engineering Command

4. Depot Operations, Defense Supply Agency, DLA

5. Waste Disposal Engineering Division, U.S. Army Environmental Hygiene Agency

6. Director of Industrial Operations, Fort Belvoir, VA.

Some of the major observations noted during the site visits are discussed below.

Anniston Army Depot

At Anniston Army Depot, large amounts of solvents are used annually for equipment cleaning and rebuilding. In 1982, bulk purchases of only one kind of solvent, PD-680, Type I (Dry Cleaning Solvent) totaled 22,500 gal. A distillation recycling unit is adjacent to the largest solvent cleaning bath in the tank rebuild facility. Contaminated solvents and solvent sludges were disposed of by contractor removal and disposal through the Facilities Engineer.

During the site visit, the following kinds of solvents were noted in use at the Depot:

1. Tricholoroethylene--used for vapor degreasing vehicle parts; degreasing equipment parts in machine rebuild shop.

2. Stoddard Solvent--used for cleaning in maintenance shops.

3. Paint solvent (a solvent mixture)--used in spray booths in paint shops.

4. Methylene chloride--used in maintenance shops.

Anniston Army Depot has an installation regulation for procuring and controlling toxic and other hazardous items (Anniston Army Depot Regulation 715-4, "Procurement: Controlling Local Purchase of Toxic and Other Dangerous Items").

Additional information was requested from the Environmental Coordinator on amounts of solvents purchased and disposed of annually, but the information received was inconclusive.

Fort Eustis

Fort Eustis, Headquarters for the Transportation School, is a relatively small user of solvents, the primary use being for vehicle and equipment cleaning and degreasing. Evaporation losses account for the major "disposal" of solvents. Contaminated solvents and solvent sludges are dumped into the oily waste collection tanks. A contractor to the installation gathers the contents of these oily waste collection tanks and transfers them to one of two large (50,000-gal) storage tanks. The contractor delivers to one tank one month and the other tank the next month, thus allowing time for precipitation of solids within the mixture in the tanks. The contractor also collects oily wastes from the tank which has remained undisturbed for a month and delivers them to the installation's boiler plant, where they supplement the regular fuel oil. This effectively disposes of the waste solvents. The Facilities Engineer anticipates a contract to clean the large storage tanks and have sludges removed. There is no specific installation regulation for solvents or hazardous materials.

During the site visit at Fort Eustis, several solvents were noted in use:

1. Dry cleaning solvent (PD-680, Type I)--used in the motor pool for parts cleaning, at Port Facility for degreasing in maintenance areas, at rail transportation maintenance shop for parts cleaning.

2. Trichlorotrifluoroethane (freon)--used in motor vehicle rebuild and maintenance shop.

Fort Bragg

Fort Bragg, a very active installation with a large population, uses solvents primarily for equipment, vehicle, and small arms maintenance. Fort Bragg has an oily waste/waste solvent collection system similar to that at Fort Eustis, and disposes of its wastes by incineration as a fuel supplement. Fort Bragg has published no specific installation guidance for the management of hazardous materials.

Several different kinds of solvents were noted in use at Fort Bragg:

1. Trichloroethane--used for vehicle engine block cleaning; small arms rebuild shop for degreasing.

2. Lacquer Remover (a solvent mixture)--used in paint shop for paint stripping.

3. Naphtha--used for general cleaning purposes, about 2200 gal used monthly.

4. Dry cleaning solvent (PD-680)--used on helicopter flight line for aircraft and parts degreasing.

5. Methyl ethyl ketone--used at helicopter flight line for paint removal.

6. B&B 3100 (aircraft cleaning compound)--used at helicopter flight line for engine flushing and cleaning.

Identification of Solvents

To identify and quantify the solvents used at Army installations, several hundred different National Stock Numbers (NSNs) for solvents were obtained, primarily from the ETIS and HMMS systems. These sources provided an extensive list of solvents and solvent items available to Army users. The Defense Supply Agency and the Logistics Control Agency were then asked to provide information about the quantities of the identified solvent NSNs purchased by the Army.

Installation Users

Based on the site visits and literature review, Army activities requiring solvent use were tabulated. Table 2 lists these activities along with typical kinds of solvents used and their primary uses.

Quantity of Solvent Use

The organic solvents of concern considered in the Solvents Management Plan fall into several Federal Supply Classes. Appendix A briefly describes Federal Supply Classes containing toxic or hazardous items. Most solvents generally occur in two of these classes and are identified by a 6810 or 6850 prefix to the NSN.

Solvents purchased through the Federal Supply system are usually found in federal supply group/class 6810 (chemicals) and 6850 (miscellaneous chemical specialties). CERL's approach to solvent identification consists of listing all of the items in the 6810 and 6850 group/class. This list was assembled using the NSNs shown in the HMIS and ETIS-HMMS and verified as being current by cross referencing with the Army Master Data File. The list was then sent to the U.S. Army Materiel Development and Readiness Command, Logistics Control Activity, Presidio of San Francisco, CA, for a demand analysis.

It is very important to quantify the Army's use of solvents so that there is a fundamental basis for the R&D and economic analysis of the various alternatives for solvent management. There seems to be no one activity within the Army that is responsible for managing of all solvents as a generic class of material. The only quantification data available on solvent use is the demand analysis. This data is for one calendar year beginning 1 December 1981 and ending 30 November 1982. Table 3 summarizes the data derived from the demand analysis for CONUS and overseas. Appendix D is a breakdown of the solvent demand analysis for the MACOMs and overseas. It should be noted that this demand analysis represents only the solvents ordered through the Army procurement system. It does not consider local procurement or bulk purchases by some of the heavy solvent users. This data is useful because it indicates

Table 2

Army Installation Activities Using Solvents

User Activity	Primary Use of Solvent	Typical Solvent Used
Vehicle Rebuilding-Depot Level	Degreasing, Corrosion Control	Dry Cleaning Solvent*, Trichloroethane
Vehicle Rebuilding-Installation	Degreasing, Corrosion Control	Dry Cleaning Solvent, Methanol, Trichloroethane
Vehicle Maintenance	Degreasing, Corrosion Control	Dry Cleaning Solvent, Glycol, Methanol, Trichloroethane
Motor Pools	Degreasing, Corrosion Control	Dry Cleaning Solvent, Glycol, Methanol, Trichloroethane
Troop Units	Degreasing, Cleaning	Dry Cleaning Solvent, Methanol, Trichloroethane
Aviation Maintenance	Degreasing, Cleaning	Dry Cleaning Solvent, Freon, Trichloroethane, MEK
Paint Shops	Paint Thinners, Lacquers, Cleaning	Usually a hydrocarbon solvent-based mixture. May include Naphtha, Toluene, Ketones
Packing Shops	Coatings	Alcohols
Munitions & Ordnance Maintenance	Degreasing, Cleaning	Dry Cleaning Solvent, Trichloroethane
Research & Development Labs	Various	Trichloroethane, Methanol, Alcohols
Facilities Engineers	Degreasing	Dry Cleaning Solvent, Trichloroethane, MEK
POL Yard	Degreasing, Cleaning	Dry Cleaning Solvent, Trichloroethane
Laundry Facilities	Cleaning	Dry Cleaning Solvent
Entomology Shop	Mixing Agents	Naphtha, Alcohols, Naphthalene
Fire Department	Practice Fires	Waste solvent mixtures which might include Trichloroethane and Dry Cleaning Solvent
Photographic Plants	Processing	Alcohols, Dry Cleaning Solvent
Printing Plants	Mixing Agents, Cleaning	Trichloroethane, Alcohols
Heating & Cooling Plant	Refrigerant Fluids	Freon, Heptane
Hospitals and Clinics	Mixing Agents, Cleaning	Alcohols, Esters, Xylene
Sanitary Landfill	As a Solid Waste	Trichloroethane
Sewage Treatment Plant	Mixing Agents	

*Dry Cleaning Solvent may also be called PD-680 or Stoddard Solvent.

Table 3

Army Solvent Usage Summary (gal)*

	(1) Hologenated Solvents	(2) Alcohols	(3) Ketones	(4) Aliphatic Solvents	(5) Armomatic Solvents	(6) Other	Total	(7) Solids
DARCOM	1,104,461	1,720	20,846	41,319	66,468	162,864	1,397,678	282,025
ARNG	4,373	8,362	8,481	69,463	9,585	6,789	107,053	3,163
MDW	0	4	46	222	18	0	290	0
FORSCOM	12,199	11,967	4,859	63,117	111,267	66,354	269,763	1,102
TRADOC	5,765	8,909	4,668	28,995	31,746	10,667	90,750	880
HSC	239	1,545	2,152	358	6,178	1	10,473	0
ACC	55	998	137	546	526	12	2,274	0
OVERSEAS	55,752	90,432	25,516	537,225	455,366	32,596	1,196,887	71,066
OTHER	104,557	211,806	6,431	25,805	76,887	5,1443	430,619	25
TOTAL	1,287,401	335,743	73,136	767,050	758,031	284,426	3,505,787	358,261

NOTES:

1) Halogenated Solvent -- Carbon tetrachloride, dichloromethane, trichlorethane

2) Alcohols -- Ethylene glycol, methanoe, denatured alcohol

3) Ketones -- Methyl ethyl ketone, acetone, methyl isobutyl ketone

4) Aliphatic solvents -- Cleaning compound, solvent, naphtha-aliphatic

5) Aromatic solvents -- Naptha-aromatic, petroleum ether

6) Other -- Corrosion removing compounds, cleaning and lubricating solvents, esters

7) Solids - p - dichlorobenzene, napothalene phenol.

*Usage from 1 December 1981 to 30 November 1982 as reported by U.S. Army Material Development and Readiness Command, Logistics Control Activity, Presidio of San Francisco, CA.

the minimum amount of solvents used by the Army; the actual amount will be somewhat higher. The data also indicate use trends. Because of their mission, DARCOM installations use more bulk solvents and more solvents used in vapor degreasers than TRADOC and FORSCOM installations.

3 DEVELOPMENT OF SOLVENTS MANAGEMENT PLAN

Based on the information obtained from the literature, site visits, and other data sources, a Solvents Management Plan was developed and prepared which contains guidelines and techniques prescribing responsibility for identifying, controlling, and disposing of solvents at an Army installation. These guidelines include a monitoring system that will control solvents procured for installation activities and units. Alternative methods of disposal are presented so that each installation may adopt those that are the most compatible with its individual needs.

The objective was to create a workable plan that would be easily adaptable to current Army procedures for solvents procurement and use, and that would have minimal impact on the workloads of Army personnel involved with solvents.

The plan is a tool for effectively controlling the procurement, use, and disposal of solvents at Army installations and is meant to reinforce existing Army policies. It compiles recommended procedures on control and management of solvents at an Army installation from the time they enter an installation until their ultimate disposal.

Solvent items specifically targeted by DOD Cosolidated Guidance--Hazardous Material/Hazardous Waste Disposal as pre-determined hazardous wastes for management control and estimate disposal by the PDO, if necessary, are:

1. F001--spent halogenated solvents used in degreasing: tetrachloroethylene, trichloroethylene, methylene chloride, 1, 1, 1-trichoroethane, carbon tetrachloride, and chlorinated fluorocarbons.

2. F002--spent halogenated solvents: tetrachloroethylene, methylene chloride, trichloroethylene, 1, 1, 1-trichloroethane, chlorobenzene, 1, 1, 2-trichloro-1, 2, 2-trifluoroethane, ortho-dicholorobenzene, and trichlorofluoromethane.

3. F003--spent nonhalogenated solvents: xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol.

4. F004--spent nonhalogenated solvents: cresols and cresylic acid, and nitrobenzene.

5. F005--spent nonhalogenated solvents: toluene, methyl ethyl ketone, carbon disulfide, isobutanol, and pyridine.

6. F007--spent cyanide plating bath solutions from electroplating operations (except for precious metals electroplating and spent cyanide plating bath solutions*).

*These solutions and sludges are turned in for processing under the Precious Metals Recovery Program and should be turned in as hazardous materials rather than wastes.

7. F009--spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process (except for precious metals electroplating and spent stripping and cleaning bath solutions*).

8. F015--spent cyanide bath solutions from mineral metals recovery operations.

Organic solvents constitute the bulk of solvents now used by the Army for cleaning and degreasing. However, when many of these solvents such as PD680 (Stoddard solvent) are purchased, they are not specifically identified as hazardous wastes, so they must be managed by the generating activity and disposed of by the Facilities Engineer.

Solvent Management Steps for Army Installations

Figure 1 outlines the pathways and requisite decisions for the inventory, procurement, use, control, and disposal of solvents. The following discussion provides a step-by-step examination of each part of the diagram.

Management

1. Command Emphasis. The installation commander can initiate and support the solvent control program, as required by AR 200-1 and AR 420-47.

2. Regulation and Guidance. AR 200-1, AR 420-47, and DOD Consolidated Guidance--Hazardous Material/Hazardous Waste Disposal provide sufficient policy information for the proper management of solvents within the Army.

3. Installation Hazardous Waste Management Board. This board consists of the installation commander, hazardous wastes generators, the Facilities Engineer, Surgeon, PDO, Safety Officer, Legal Counsel, and Environmental Officer. The board considers solvent policy matters, and optimizes and resolves solvent management alternatives.

4. Solvent Inventory. All of the solvents purchased by the installation should be inventoried for management purposes. The supply activity could conduct this inventory.

5. Identification of Specific Solvents for Control. The Environmental Officer and the Industrial Hygienist can probably best identify the specific solvents which need control. The Hazardous Waste Management Board would be involved in the final decisions and actions dealing with control.

Supply

6. Solvent Supply. The mission of the supply activity is to provide Army activities with the types and quantities of solvents needed to accomplish their mission.

7. Solvent Control. Certain solvents become hazardous wastes upon generation. These solvents should only be issued from the supply system to activities that have a requirement to use them and have the proper facilities to manage and dispose of the waste products in an approved manner.

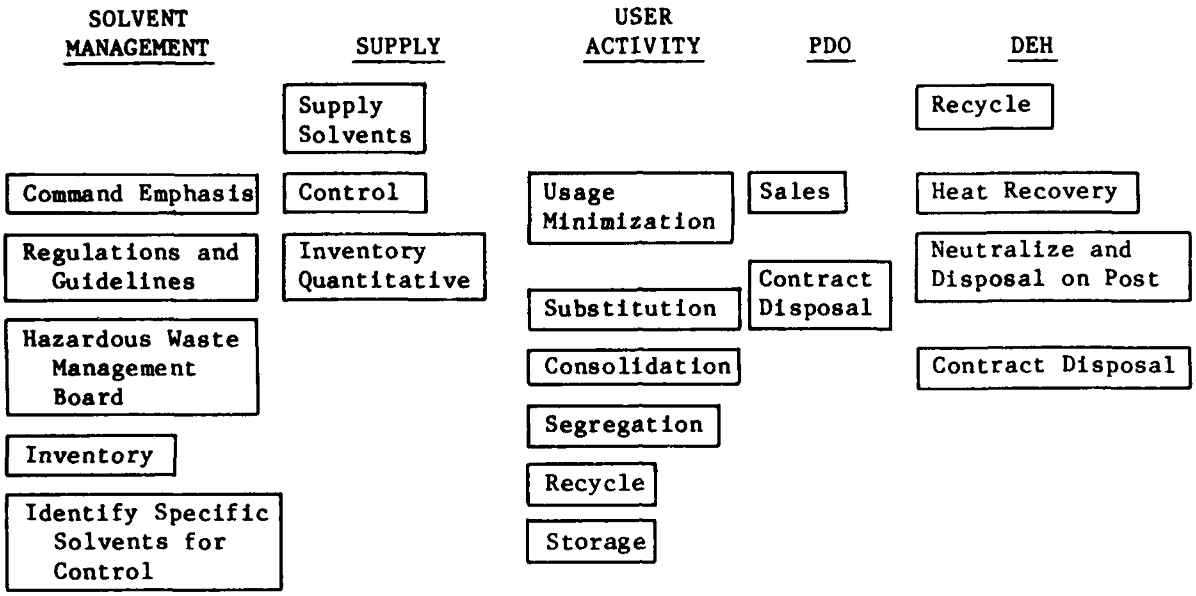

Figure 1. Solvent flow diagram.

8. Quantitative Inventory. A quantitative inventory conducted by the supply activity of all solvents entering the Army supply system is required for meaningful solvent management.

User Activity

9. Minimization of Solvent Usage. Each solvent consumer should try to use as little solvent as possible and still effectively accomplish his/her assigned mission.

10. Substitution. Each activity should examine its solvent requirements and determine whether nonhazardous solvents or processes could be substituted and still accomplish its mission.

11. Consolidation. Each solvent-consuming activity should examine its requirement for solvents and order as few different types of solvents as possible.

12. Segregation. Waste solvents must be segregated to maximize their value for recycling and re-refining.

13. Recycle. The user activity is usually the best place for recycling solvents, especially if it generates a large quantity of solvent wastes and the recycling process is fairly uncomplicated.

14. Storage. Each solvent user activity should provide adequate waste solvent storage. An attempt should be made to use the containers that the virgin solvent was delivered in for waste solvent storage.

Defense Property Disposal Office (DPDO)

15. Sales. The mission of DPDO is to sell waste solvents which have marketable value. This value is enhanced when the user activity segregates its waste solvents and can identify the type of contaminants present in the solvents.

16. Contract Disposal. The DOD Consolidated Guidance--Hazardous Material/Hazardous Waste Disposal has designated certain solvents as predetermined hazardous wastes upon generation. Each DPDO has been directed to dispose of them. Segregation in storage and handling by the user activity makes disposal much easier and less costly.

Directorate of Engineering and Housing (DEH)

17. Recycle. If large quantities of solvents are generated, it may be possible to establish a facility to purify and redistribute solvents to users. Appendix B contains economic and technical guidance for several recycle options.

18. Heat Recovery. When economically and environmentally feasible, burning waste solvents for heat recovery is another method of solvent management. Appendix B contains some economic and technical factors to consider when waste solvents are burned.

19. Neutralization and Disposal On-Post. Waste solvents which are not reusable and not burnable can sometimes be neutralized and disposed of on-post.

20. Contract Disposal. When no other forms of waste disposal can be used, contract disposal is the last resort. Care must be taken so that a reputable contractor who holds the proper permits disposes of the hazardous wastes. Appendix B contains information about this method of disposal.

The decision diagram forms a vital part of solvents management. The essential elements are:

1. Responsibilities of installation personnel

2. Establishment of Hazardous Waste Management Board

3. Inventory of solvents used at an installation

4. Development of a controlled (restricted) solvents list

5. Minimization and/or elimination of solvent use by:

   a. Process and/or production modification

   b. Solvent substitution

6. Solvent purchase control through the installation's Supply Division

7. Proper handling and storage of solvents

8. Spent solvent disposal alternatives

   a. Examination of recycling/reclamation of solvents

   b. Development of proper disposal alternatives.

Installation Responsibility for Solvents Management

In addition to the installation commander, several staff functions and individuals are responsible for implementing and managing the Solvents Management Plan. Also, the Hazardous Waste Management Board should be created according to the latest draft of AR 420-47, Solid and Hazardous Waste Management, and would have the final authority on the installation's policy and specific actions dealing with solvent management.

Responsible Personnel

Solvents management can be readily incorporated into the structure and function of existing installation offices and duties. Individual concerns are:

Installation Commander.

1. Has overall responsibility for the hazardous waste management system, including compliance by tenant activities and subinstallations.

2. Chairs or appoints a chairperson for the Installation Hazardous Waste Management Board.

3. Insures that the Facilities Engineer has enough support to carry out his/her function.

4. Insures that all hazardous waste generators comply with applicable regulatory requirements.

Director of Industrial Operations.

1. Investigates recycling options.

2. Could operate central recycling unit, if installation acquires one.

3. Devises a formula for equitable redistribution of product from recycling center.

4. Establishes criteria for substitution in processes under his/her control.

Director of Engineering and Housing.

1. Initiates work orders to procure equipment and materials for solvent collection and storage areas.

2. Collects solvent wastes and transfers them to storage tanks.

3. Keeps logs and records concerning collection, storage, and handling of waste or contaminated solvents.

4. Collects and transfers solvents to ultimate disposal site, or supervises contract for collection, transfer, and/or disposal.

5. Collects solvents for transfer to installation recycling center and transfers product back to user.

6. Investigates recycling options.

Environmental Officer.

1. Submits all required Federal, State, and local environmental permits, manifests, etc., in the name of the installation commander.

2. Participates in initial installation survey of solvents and solvents use.

3. Recommends solvent substitution and minimization options.

4. If necessary, authorizes solvent items as controlled items.

5. Acts as Executive Agent (Chairperson) of Solvents Control Team.

Installation Property Disposal Officer.

1. Participates on Hazardous Waste Management Board.

2. Disposes of required items by contract.

3. Arranges for sale of waste solvents.

Hazardous Waste Management Board

This informal panel is chaired by the installation commander or his/her representative and serves as a forum to consider, optimize, and resolve hazardous waste management alternatives. Membership on the board must include representation from the hazardous waste generator, the Facilities Engineer, the Surgeon, the Property Disposal Officer, the Safety Officer, the Legal Counsel, and the Environmental Officer. An existing suitable forum, such as the environmental council, may be used instead of establishing a new board. The board is responsible to the installation commander and advises him/her on the implementation of hazardous waste management policy.

Permits

The Environmental Officer is usually responsible for initiating and filing all required Federal, State, and local permits, manifests, and reports that concern solvents. This includes application for U.S. Environmental Protection Agency waste generator permits and storage site permits.

Solvents Inventory

The Army Installation Commander is directed by AR 40-5, Medical Services, Health and Environment,[4] to be responsible for protecting personnel from environmental health hazards and for setting up adequate environmental pollution abatement measures. This regulation provides the Commander the latitude to address solvents management and to implement it as part of the responsibilities of the Hazardous Waste Management Board. It also allows him/her to direct the Industrial Hygienist (IH) and Environmental Officer (EO) or DIO to inventory the solvent use of all activities on the installation, including tenant organizations. Specifically, AR 40-5 calls for, at the minimum:

1. Inventory of health hazards assessment and protective measure evaluation of industrial and other operations, including research and development activities

2. Inventory of toxic chemicals and agents at user level to assure adequacy of preventive measures and recommend substitution of less toxic substances when appropriate

3. Establishment of environmental controls to assure safe and adequate water supply and proper disposal of sewage and industrial wastes.

To carry out the requirements of AR 40-5, the solvents inventory of an installation will:

1. Provide a list of all activities using solvents

[4]Medical Services, Health and Environment, AR 40-5 (Department of the Army, 1977).

2. Provide a list of all types of solvents used at each location for the identified activities

3. Provide the quantities of each solvent used at every location

4. Provide an installation-wide survey of existing disposal or recycling methods at each location.

The inventory will also facilitate decisions about possible solvent substitution, solvent items that should be restricted or declared unauthorized, solvent recycling opportunities, and disposal options.

Copies of the inventory should be provided to the Fire Prevention and Protection Branch, the Safety Office, and the Health Clinic or Hospital. In cases of worker accident or environmental contamination by solvents, any or all of these offices may be involved, and such an inventory could be valuable.

Unauthorized Solvents List

The installation-wide inventory will probably identify and list solvents that should be banned for certain uses because of their extreme toxicity, ignitability, or the hazards they create upon disposal. These solvents should become "controlled items," and only available to activities which have a legitimate need for them. The list can be a local supplement to an Army- or DLA-generated "controlled solvent items list." The installation's additions to the Army-wide controlled solvents list can then be added to its Supply Division's computer, to be coded as a restricted item. This insures that users can procure only authorized solvents through the official supply channels.

The software in the Supply Division's master computer system allows for a variety of control or hazard codes to be placed on any supply system item. Upon recommendation of the IH or EO, the decision to restrict a solvent item may be made by either the Defense Logistics Agency (DLA), DA, or an installation commander.

Periodic follow-on surveys made by the IH and/or EO will identify any new solvent items that have been procured by users since the original inventory and their conditions of use. A decision may then be made about whether they should be placed on the controlled list. In making such decisions, the IH/EO should have access to the Hazardous Materials Information System (HMIS). This system gives physical and chemical data, as well as handling and disposal information on hazardous items. Guidelines for creating a controlled solvent items list include:

1. Advise installation users of the DLA-, DA-, and/or installation-generated restricted solvents list.

2. Add any solvent items identified through the installation's solvent inventory that the installation commander wishes to designate as a controlled item.

3. Code all controlled solvent items into the installation's supply computer system.

4. Recommend to users substitutions for restricted solvents.

Minimizing Solvent Use

Process Modification

The installation should emphasize process control, value analysis, and process modification; however, minimizing or eliminating the use of solvents may require a Command headquarters decision.

Army research and development laboratories are examining various processes and products that would minimize or eliminate the need for solvents in order to prevent or abate pollution. Examination of current industrial processes which use solvents may indicate efficiencies which might be attained through product reformulation, process modification, and equipment redesign. Any of these may change the way solvents are used in an industrial process or in maintaining fixed and mobile equipment. In addition, user activities are encouraged to suggest ways to improve the quality of and/or simplify their tasks. This may also minimize solvent use.

Solvent Substitution

Several factors determine what solvent is used for a particular military application: performance (ability to meet job standards and specifications), availability, tradition, cost, toxicity, and safety. The importance of these factors has often been considered in this order. However, recent regulations such as the Occupational Safety and Health Act, the Toxic Substances Control Act, and the Resources Conservation and Recovery Act have emphasized the toxicity and safety aspects of hazardous materials and wastes. As a result, users or personnel responsible for user safety have substituted less hazardous solvents whenever possible.

Solvent substitution suggestions can come from the IH, EO, or personnel at the user activity. However, the Army rigorously controls most industrial processes, testing, calibrations, cleaning activities, etc., so military standards and specifications must be consulted about solvent substitution. In some cases, the specifications and standards list substitute compounds. Also, the Army Master Data File may show where substitute compounds can replace a hazardous solvent currently being used. The Master Data File and applicable standards and specifications must initially be consulted when making solvent substitutions.

Where specifications state that the less hazardous solvent is acceptable, it should be adopted. If specifications do not indicate alternative compounds for a specific application, then the user activity should investigate whether the substitute solvent will perform as well as the original solvent. Production capacity and effectiveness must be weighed against worker safety and prevention of pollution.

Recognizing that only DA or DLA may authorize solvent substitution for some activities, the installation's EO, IH, Safety Officer, or user personnel should still consider substituting less hazardous solvents, and make such recommendations to a higher command.

Addressing the specific merits of various solvents is possible on a theoretical basis, if their respective chemical and physical properties are considered. However, when specific solvent uses and applications are considered, the issue of solvent substitution soon becomes quite complex and less amenable to rigid protocols. Therefore, the decision logic diagram shown in Figure 2 has been drawn up to help the facility and user activity personnel, Safety Officer, or Industrial Hygienist systematically review solvent use at their installations.

As shown in Step 1 of Figure 2, process modification to eliminate solvent usage should be examined. For example, alternative cleaning methods may be detergent/water solutions (pressurized or nonpressurized), hot water or steam cleaning, or abrasive materials (e.g., sand-blasting). These alternatives could eliminate the use of hazardous solvents, which would greatly decrease the exposure hazard for workers and might also preclude the problem of hazardous material disposal.

If a user has determined that solvent elimination is not a viable alternative, then other solvents can be considered according to the criteria shown in Steps 2 through 4 of Figure 2. Table 4 lists some widely recognized solvent-to-solvent substitutes.

Procurement of Solvents

The user is ultimately responsible for solvent selection and will be directed by specifications, standards, and performance results. However, the installation supply system can be an important control point, because it can prevent the procurement of certain solvents. All normal requests and local purchase requests go through an installation's Suppy Division and are processed by their NSNs through the supply computer system. Only nonstandard item requests (those with no assigned NSN) are processed differently.

The installation supply system is a "last line" control check on the procurement of restricted solvents. During the inventory, the IH and EO should have recommended which solvents are acceptable, which are good candidates for substitution, and which are unauthorized. The user must decide which solvents are acceptable for the specific use and which ones will be ordered.

Users request solvent items by NSN and the Supply Division confirms them for validity and availability. The Army's computerized supply system has a control or check system built into its program which "kicks out" improper or unauthorized requests. It already responds to several pre-established controlled items (identified by NSN), such as weapons and munitions. The system also allows for substitution recommendations; these equivalent-item

Decision Logic			Remarks
1 Modify process/application to eliminate use of Solvent A?	YES	Investigate alternatives	Where MIL SPECS do not clearly indicate substitutes, consider using such alternatives as: abrasives, detergent/water solutions, steam.
NO			
2 Consider substituting Solvent B for Solvent A			
3 Threshold Limit Value (TLV) of Solvent B less than TLV of Solvent A? (TOXICITY CRITERION)	NO	Do not use Solvent B	Considerations include suspected carcinogens, vapor toxicity, liquid toxicity.
YES			
4 Nat'l. Fire Protection Assoc. Flammability rating of Solvent B lower than Solvent A? (FLAMMABILITY CRITERION)	NO	Do not use Solvent B	Must consider reactivity of Solvent B with other process chemicals. Is flashpoint below 60°C?
YES			
5 More personal protection required to use Solvent B than Solvent A? (WORKER HEALTH CRITERION)	YES	Do not use Solvent B	Is special ventilation needed; flame sources; safety can; grounding; respirator; goggles; face shield; coveralls?
NO			
6 Is Solvent B better than Solvent A in meeting job specs? (PERFORMANCE/USE CRITERION)	YES	DECISION COMPLETE USE SOLVENT B	Production efficiency; cost; ease of disposal; maintain job quality.
NO			
7 Do not use Solvent B. Select Solvent C and recheck criteria.			

Figure 2. Solvent substitution decision diagram.

Table 4

Solvent-Solvent Substitutions

Solvent	To Be Replaced By	Comments
Methanol	Isopropanol	Methanol is a highly toxic compound
Methyl Ethyl Ketone (MEK)	Acetone	
	Ethyl Acetate	
	Aliphatic Naphtha	
Toluene	Stoddard Solvent Varsol	
	1,1,1-Trichloroethane	
	Acetone	
Trichloroethylene	1,1,1-Trichloroethane	Trichloroethylene is a possible carcinogen and should be eliminated from use
	Methylene Chloride (Dichloromethane)	
Xylene	Stoddard Solvent Varsol	
	1,1,1-Trichloroethane	

substitutes are entered into the Army Master Data File system at Army and/or DLA level. Item managers within the installation Supply Divisions recommend substitutes for items being phased out because they are out of stock or obsolete.

One possible control is that a list of controlled solvents be coded into the supply system computers and any additional solvents identified by the local EO or IH survey be coded as controlled items. Controlling these selected solvents in the supply system keeps users from obtaining them. Control codes on NSNs "bump" the request from the supply computer for review and examination by the specific item manager. He/she may take one of several actions, depending on the control code; in the case of controlled solvents, it would involve cancelling the order request and returning it to the user with

an explanation of why it was not processed. It is then the user's responsibility to check the AMDF for listed substitutes, or to find another item to replace the controlled one and submit a new request.

Local purchase items and standard requests are processed similarly, and controls can also be placed on these items. Nonstandard item requests (those not in the Federal Supply list) are given a Management Control Number by the Document Control File Section for processing; this type of request would normally not be subject to the control codes. Established periodic surveys by the IH and EO would identify solvents procured in his way, and decisions regarding their use would then be made.

Since the supply system contains control mechanisms, adding more controlled items does not put an extra burden on the item managers. However, the best controls for solvents use are at the user level; the coding of items in the supply system is only a built-in check system.

Handling and Storage of Solvents

As shown in Table 2, Army installations generally include activities or operations that involve a wide range of solvent users. When solvents are received from Depot or Supply Division warehouses, it is assumed that they are properly packaged for handling. DLA is incorporating information from the HMIS into its shipment manifests; this means that instructions on packaging, handling, spill clean-ups, fire-fighting, etc., will be on all hazardous items that the user receives. Therefore, the focus must be on handling contaminated or waste solvents after use and prior to disposal.

Short-term storage of hazardous wastes, including solvent wastes, for less than 90 days requires proper packaging and Department of Transportation (DOT) identification and labeling. Long-term storage (exceeding 90 days) requires RCRA permit through the EPA and/or the State in addition to proper packaging and DOT labeling. The handling and storage guidelines for solvent wastes discussed in the following three sections apply to Army installations. Waste solvents that are being stored for recycling are not classified as hazardous wastes and are not required to comply with the hazardous waste regulations; however, sound management practices should be used.

Solvent Segregation at the Source

Depending on the ultimate fate of the waste material collected, source segregation may or may not be required. However, if an installation commander and DIO are considering recycling solvents, or wish to increase resale value through PDO, the waste solvents should be segregated.

Public Law 97-214 allows an installation to keep 100 percent of the proceeds from the sale of its recycled materials. These funds can be used to operate, purchase, or update equipment for recycling and reclamation activities, or may be placed in the installation's Morale and Welfare Fund; however, no more than 50 percent of the funds may be used for other pollution abatement programs. It is advantageous to the installation to segregate waste solvents, even if recycling is not anticipated. The resale value of "clean"

waste solvents is much greater than for solvent mixtures or for solvent/oily waste mixtures. DLA encourages the segregation of waste solvents, since several industry users have stated an interest in acquiring them.

In the reclamation process, the equipment's separation capabilities may be the limiting factor. The end user requirements will also be a major concern. If reclamation is not the desired mode, then further waste handling and storage operations insure personnel safety and environmental protection. When segregation by type is desired, solvents should be separated into the following categories: hydrocarbon solvents; chlorinated solvents, freon; oxygenated solvents; and carbon- and paint-removing solvents.

If segregation by kind of solvent is desired (i.e., Stoddard solvent, freon, etc.), 55-gal storage drums must be provided and marked so that each solvent is poured into the appropriately marked container. Whenever possible, the original container with appropriate labeling should be used as the waste collection container. Reuse of the original container for the waste solvent will help prevent further contamination of the waste solvent.

Waste/Contaminated Solvent Collection

The following are some accepted guidelines for collecting waste or contaminated solvent solutions:

1. Waste solvent drums, preferably the same drum that the pure solvent was shipped in, should be made available to users and placed in appropriate and safe areas.

2. Metal safety cans should be used to store and transfer waste solvents. Glass or plastic containers should not be used. Safety rubber gloves and aprons should be worn when transporting waste solvents.

3. Where a layer of water is formed in the waste solvent, it should be decanted before the solvent is transported.

4. Inhalation of solvent vapors should be avoided; a vapor respirator is required when handling solvents with toxic fumes.

5. Waste or contaminated solvents should be placed in metal drums that are no larger than 55 gal.

6. Metal drums should be located in fenced and locked areas.

7. Existing labels, numbers, and printing should be marked over or removed from the storage drums. Each drum containing waste solvents should have a number and a new label that conforms to DOT regulations.

8. Safety rubber gloves, apron, and splash shield should be worn when pouring solvent into a drum.

9. Each drum should be filled to no more than 5 in. from the top.

10. Filled drums should be labeled "FULL".

11. Drums being filled should be labeled "IN USE".

12. Specific waste solvent, quantity, drum number, unit generating waste, and initials of the person placing solvent in the drum should be recorded.

13. Any spills during duty hours should be reported to the EO. During nonduty hours, spills should be reported to the Officer of the Day or to the Non-Commissioned Officer of the Day, who will contact appropriate personnel.

14. Bung should be replaced after filling drum.

15. Area should be locked upon leaving. The area should always be locked except when drums are being filled or when they are removed by the FE.

Central Storage Point

Central storage facilities must be provided when waste solvents are picked up at the point of use, but not immediately transported off the installation or to the point of disposal. Minimal guidelines are:

1. Storage tanks should be in a locked and fenced area, away from other activities and buildings.

2. For solvents segregated at the point of use, separate tanks should be available for each specific solvent.

3. Records of quantities and types of solvents added to storage tanks should be maintained.

4. Wastes should be tested to determine their value for resale or reclamation.

Solvent Disposal Alternatives

There are several options for disposing of solvents. Appendix B contains detailed economic analyses of five solvent disposal alternatives: recycle on post, recycle off post, sales, service contract, and combustion in the Army's industrial boilers.

Several actions can be identified for unused solvents for which no further immediate use is anticipated. The user may return such solvents to the Supply Division and receive "credits" against future orders. The Supply Division may either store the solvents for redistribution within the installation, or may consolidate them for transfer to the Defense Property Disposal Office for off-site resale. DOD Manual 4160.21-M[5] describes the requirements for these solvents.

[5]Defense Disposal Manual, DOD 4160.21-M (Department of Defense, July 1979).

The following are options for management of spent solvents and/or solvent wastes:

1. Reclamation for reuse in the same application or process, either in-house or by contract (Appendix B, Options 1 and 2).

2. Sale of spent solvents to contractors/reprocessors through the PDO (Appendix B, Option 3).

3. Solvent supply/waste solvent disposal through a service contract (Appendix B, Option 4).

4. Blending with fuels (Appendix B, Options 1 and 2).

Reclamation for Reuse

If an installation commander anticipates that recycling is an attractive option, the various recycling alternatives and opportunities should be investigated. Such studies may include:

1. Segregation and collection of waste/spent solvents

2. Point-of-use solvent-recovery units

3. A single installation solvent-recovery unit

4. Service contract with a reclaimer

5. Donation of spent solvents to a Government-owned reclamation center

6. Sale through PDO.

When considering a recycling option, a careful system and cost analysis related to the installation's specific operational characteristics must be made (Appendix B). This information will provide the installation commander with a sound basis for deciding what recycling option, if any, should be pursued. Some pertinent factors to consider for an installation solvents recycling center include:

1. Whether there is an existing reclamation unit

2. Capital investment for new equipment

3. Capacity of proposed unit to recycle more than one type of chemical

4. Cost of reclaimed solvent vs. newly procured items (with capital and operating and maintenance costs considered)

5. Cost of storing, collecting, and transporting solvents to and from the recycling center

6. Rate of return and amortization on recycling equipment

7. Cost of recycling mixed solvents vs. single-solvent items

8. Cost of recycling all solvents used on-post (including freon) or only selected solvents

9. Development of a redistribution formula and procedures for recycled products

10. Income from sale of reclaimed product

11. Cost of preferred or current disposal option.

Despite the costs of recycling, there are benefits in reclamation. Depending on the system and degree of contamination, 70 to 95 percent of the waste solvent can be reclaimed. As costs for buying new solvents rise, reclamation becomes more attractive. Costs for reclaiming solvents can range from much less to slightly more than the cost of new solvents. However, the cost of recycling is not the only factor to consider; since solvents are generally considered hazardous materials, reclamation may be the only feasible option.

There are usually several solvent recycling or reclamation opportunities at a typical Army installation. Special consideration should be given to the following:

1. Point-of-Use Recovery Units. Recovery units at the point of use may be feasible when an installation activity generates relatively large volumes of specific solvent wastes. Manufacturer's information and documented cases at military installations show that this option is usually less expensive than buying new solvents. However, before any specific recovery system is procured, the installation should have the manufacturer demonstrate the equipment, and then test the recovered solvent to insure that it complies with military specifications.

2. Installation-Operated Recycling Center. A central reclamation system may be feasible when several installation activities generate enough solvent wastes to warrant recovery. Segregation of the wastes is critical to such an operation, and sufficient quantities of each type are required to make the system economical.

Recovery of selected solvents from a mixture may be complicated and expensive. The end products must conform to military specifications, and proper storage and packaging for redistribution are important considerations. The installation directorate responsible for operating the recycling center must establish a formula and specific procedures for redistributing the reclaimed product to the users. Appropriate accounting procedures will be required for turn-in and redistribution.

3. Service Contract, Solvent Reclamation. One alternative to purchasing or operating a system is contracting out solvent supply and waste solvent disposal. The main advantage of this method is that an installation need not commit capital and operating funds or personnel to a recovery system. The contractor should be reputable and experienced, and should demonstrate production of a quality solvent product.

Contractors usually demand segregation and uniformity of waste materials. Service contract reclamation may cost more per gallon than an installation recycling center, partly due to transportation and packaging. High recycling costs may preclude the reclamation of small quantities of hydrocarbon solvents, but the high costs may be offset by volume for larger quantities of these solvents. Freon and chlorinated solvents whose replacement values are substantially higher than those of hydrocarbon solvents can be economically reclaimed in smaller quantities.

After carefully examining the technical aspects and associated costs of various alternatives, an installation may decide on a combination of recycling options (e.g., one point-of-use recovery unit and a service contract, or one point-of-use recovery unit and donation of segregated solvent wastes to another Government-owned reclamation center). Another option may be reclamation and reuse of certain solvent types or groups and the disposal of the others.

Recycling at an installation can be a very simple procedure, or it can be an extensive reclamation process, depending on whether the wastes have been segregated at the point of use. An example of a very simple and effective recycling procedure is collecting spent Stoddard solvent in drums. If the drum sits undisturbed for a few weeks, the suspended solids will settle out, leaving a clarified solvent suitable for many uses. Sometimes, the decanted solvent is of higher purity than the originally procured item (e.g., Stoddard solvent which has been allowed to sit undisturbed).

Chemical processes may be required to reclaim a mixture of several solvent types, or specifically designated solvents. There are several types of chemical processes: distillation (direct or coil heated), fractionation (batch or continuous), and vapor recovery systems using carbon adsorption techniques. Appendix C provides applicable vendor information.

Distillation. Direct steam injection is preferable for water-immiscible wastes containing mixtures of low-boiling solvents whose boiling points differ markedly (more than 15°F). This type of process is highly efficient and has minimal operating problems. Coil-heated stills are built so that the steam passes through coils submersed in the solvent mixture, instead of being injected directly; alternatively, the coils may contain heat transfer fluids or be heated electrically. These types of units are limited in handling solvents of high viscosity or high solids content.

Design variations of the distillation mechanism include units with surface scrapers and small distillation/condenser cabinet units which distill waste solvents directly from a drum. The latter variation is semi-automatic and is useful for applications where a low rate of recovery (50 to 100 gal per day) is suitable.

Fractionation. Fractionating columns may be designed to separate solvent mixtures which contain close-boiling fractions. Reclamation of mixed solvents may be possible using this procedure; however, source separation of waste solvents permits reclamation by less costly procedures. This process is routinely used on either a batch or continuous basis in the chemical and petrochemical industries; however, it represents a major capital investment

for a single facility. This type of equipment might be cost-effective for a regional reclamation center which receives wastes from a number of facilities.

Vapor Recovery Systems. For volatile solvents, vapor recovery systems are designed to adsorb the vaporized chemical onto activated carbon which may be reused many times before it requires regeneration. The solvent is generally desorbed with steam to yield a clean, usable product. If the vaporized solvent has combined with the water vapor, additional separation and distillation may be required. This type of process is also adaptable for a regional reclamation center which processes large quantities of solvents.

Blending With Fuels. For facilities generating small volumes of solvents, blending them with waste oils to supplement fuel is often a satisfactory alternative. Concentrations of low-flash solvents should be kept small in the final blend to avoid explosion; halogenated solvents should be kept below 1 percent by volume to minimize corrosion of the burner system and potential environmental hazards. The blend concentration is best determined by analytical testing. Facilities generating significant quantities of chlorinated solvents might consider sale to cement manufacturers, since cement kilns operate at high enough temperatures (about 2100°C) to decompose most organic compounds.

Incineration. Incineration is one of the most costly options, since the design, installation, and operation of an incinerator which can dispose of organic waste, yet still comply with existing air pollution regulations, is expensive. Incineration may be considered to be more cost-effective if carried out on a regional basis; however, other disposal methods should be given higher priority. The types of incinerator design vary, depending on specific requirements, but generally include the following types: vortex incineration, rotary kiln, rotary hearth, multiple hearth, fluidized bed, or fume incineration. A special application of incineration is the disposal of highly toxic organics on shipboard, such as: PCBs, DDT, 2,4-D, and other herbicides. Guidelines for incineration are similar to those for fuel supplementation.

Landfill. The RCRA controls landfill disposal by establishing disposal criteria and acceptable site designs. This legislation also requires the waste generator to adequately characterize the wastes and to be responsible for its proper disposal and for the integrity of the landfill. If the wastes are classified as hazardous, all these major criteria must be considered. Landfills must be designed, constructed, and operated in accordance with 40 CFR 241, 40 CFR 247, and any local and/or State laws.

Congress is considering ordering the reorientation of the national hazardous waste management program away from land disposal. Other disposal methods, such as incineration, recycling, stabilization, and chemical fixation should be used instead. Land disposal is inadequate for safe, long-term disposal of hazardous wastes and may not be an option open to installations in the future. For instance, California has outlined a program to phase out land disposal of toxic wastes, and 30 states have set policies to encourage alternatives to land disposal of hazardous wastes.

Installations considering landfilling of solvent wastes and sludges must be aware of current State laws, the stringent monitoring requirements, and the

possibility that land disposal may only be a near-term solution to disposal problems. With changing laws, an installation may soon have to shift to other disposal techniques. A few pertinent guidelines for landfilling hazardous wastes include:

1. Proper packaging of the solvent wastes

2. Siting so that any runoff or accidental spills do not enter water supply, endanger human health, threaten plant and animal life, enter human and animal food chains, migrate off the installation, or create noxious odor problems

3. Having full containment with clay cap or synthetic impermeable liners and leachate collection system

4. Having adequate monitoring wells in and near the landfill site

5. Having an adequate monitoring program for the landfill area

6. Having a spill containment/removal plan

7. No disposal of liquid wastes in the landfill

8. Consideration of landfill disposal only as a "last resort" alternative

9. Meeting all Federal, DOD, State, and local regulations and ordinances regarding landfill practices.

Sale Through Property Disposal Office (PDO). When waste solvents are turned in to the installation Property Disposal Office, the PDO becomes responsible for their disposal. The first option for PDO is to try to sell the wastes to private industry. In some cases, the interested buyer may be a solvent reclaimer. Depending on the firm, the following may be important considerations in selling solvent waste through the PDO:

1. Reclaimers sometimes prefer to return their products to the original users. This enhances the incentives to segregate wastes and minimizes undesirable contaminants.

2. Representative samples of waste solvents and some assurance of supplies are required for reclaimers to estimate the value of reclaimed products and processing costs.

3. Due to costs of reclamation and their higher original procurement costs, oxygenated and halogenated solvents are of prime interest.

4. Solvent mixtures and low-cost hydrocarbons are generally costly to reclaim, and it may not be economically viable to do so.

PDOs emphasize segregation of waste solvents by type, since contractors will pay more for segregated solvents. This is beneficial, since the funds from the sale revert directly to the installation.

Contractor Disposal. The installation may elect to dispose of solvent wastes through a contractor. In this case, the method of reclamation, resale, consumption, and/or ultimate disposal is then largely the contractor's decision (assuming regulatory compliance). The installation should only contract with a firm that has a permit for solvent disposal.

Illegal Dumping. Spent solvents or solvent-contaminated wastes must never be disposed of by dumping into either water bodies or onto land. Dumping is illegal and subject to severe penalties by Federal and State laws. The EO should always be alert to any dumping actions that occur within an installation's boundaries and immediately take corrective steps to clean up and properly dispose of the contaminated materials.

Manufacturers of Solvent Recovery Equipment

Thirty-five firms involved in the reclamation, disposal, or manufacture of various types of solvent recovery systems provided information on solvents recovery. These were analyzed and grouped according to the following technologies:

1. Distillation/fractionation processes (17 responses)

2. Adsorption processes (9 responses)responses)

3. Refrigeration/condensation processes, also known as vapor recovery (4 responses)

4. Contractor reprocessing (2 responses)

5. Disposal processes (2 responses)

6. Miscellaneous (1 response).

Appendix C provides the complete list of the responding corporate names and addresses.

Analysis of the system showed that the distillation/fractionation units generally varied in reprocessing capability and size; smaller units could be installed easily at a given activity to serve as point-of-use recovery systems, while larger scale-up versions would be more appropriate for installation-wide reprocessing or regional centers for solvent recovery. The same is true for adsorption and refrigeration/condensation process units, where economies of scale may be the decisive factor in unit process selection. The "contractor reprocessing" responses represent firms that will install small (55-gal) units and will service them by periodically replacing solvent and removing sludges; these types of units are often used in automobile maintenance shops and other small operations requiring parts cleaning. Several companies also offer deep-well injection and incineration as ultimate disposal options.

Solvents Reclamation Centers

Solvent reclaiming plants which use various techniques are located throughout the United States and have been successfully reprocessing a wide variety of solvents. Some observations about their operations include:

1. Reclaimers require assurance that users will send a steady supply of waste solvents to the plant.

2. Reclaimers prefer solvent wastes segregated by type.

3. Reclaimers prefer to resell the product to the original user.

4. Reclaimers are more interested in reclaiming halogenated solvents than other types.

5. Reclaimers may pay for halogenated waste solvents.

6. Reclaimers may charge the user for reclaiming solvent wastes.

7. Charges vary depending on amount, type, quality, and whether the original user will buy back the product.

Appendix C provides a list of solvent reclaimers.

User Evaluation of the Solvents Management Plan

User participation in the Solvents Management Plan is essential if an installation intends to reduce its use of solvents and consequent accumulation of solvent wastes. The best control of solvent use is at the user level. Shop personnel and shop foremen are most aware of how each solvent is used in the work area. They are also the most qualified to judge the performance of replacement chemicals (solvents or other organics) and substitute methods and processes. The Solvents Management Plan stresses the participation of these persons in decisions regarding solvent substitution, process and equipment modification, performance, and evaluation of these procedures. In fact, the user level is usually where methods for minimizing solvent use are initiated.

Inclusion of the user is vital to implementing the Solvents Management Plan. If an installation decides to use solvent recovery and recycling, or if several installations form a regional reclamation center, or if solvent collection for resale to a contractor is desired, then user personnel must be alerted to distinguish solvents from other chemicals being used. User personnel must collect and separate solvents at appropriate collection sites, either at the point of use, or at central locations.

The educational issues of solvent safety, use, minimization, and recovery/reclamation should be focused toward the persons actually handling and working with the compounds. In most cases, these will be shop personnel, shop foremen, troops, and supervisors in industrial, vehicle, aircraft, and ordnance maintenance functions.

Sources of Information

Several sources of information on hazardous materials are available to the IH, EO, or other concerned individuals. Questions regarding health effects, physical properties, storage, transportability, etc., can be answered by referring to various data banks within the Government or the private sector. Some of these information sources are:

1. U.S. Army Corps of Engineers' Hazardous Materials Information System (HMIS)

2. Defense Logistics Agency Hazardous Materials Technical Center (HMTC)

3. The Army Environmental Hygiene Agency's Industrial Health Hazards Inventory (IHHI)

4. The Navy Consolidated Hazardous Item List (CHIL)

5. The National Chemical Transportation Emergency Center (CHEMTREC), a branch of the Chemicals Manufacturers Association. This group has been mandated by Congress to be an emergency response center.

6. The U.S. Coast Guard's Hazardous Chemical Data System (CHRIS)

7. Various U.S. Environmental Protection Agency publications and documents, including the Toxic Substance Control Act Inventory (TSCA Inventory) and Hazardous Waste List

8. U.S. Army Development and Readiness Command's Hazardous Materials Data File, which is part of the Army Master Data File

9. EPA regional offices.

4 SUMMARY AND RECOMMENDATIONS

A feasible "cradle-to-grave" Solvent Management Plan has been developed for use at Army installations to effectively control the procurement, use, and disposal of solvents (Chapter 3). The plan provides guidance on minimizing solvent use; substituting less toxic solvents when possible; minimizing solvent wastes; properly handling, storing, and disposing of solvent wastes; and recycling of solvent wastes.

On the basis of this research, the following recommendations are made:

1. Accurate data on solvents used within the Army should be collected. DLA should be aware of the amount of solvents purchased; this amount should be entered into the computer for reference.

2. Solvents which should be restricted and/or controlled for use by installation users should be identified and incorporated within the Army Master Data File, which lists all Army purchases. A method should be devised to flag these solvents within this file to note them as hazardous materials which require special management.

3. The Army should select an installation to test the Solvents Management Plan.

4. The possibility of installations forming regional recycling centers should be investigated.

5. A research and development program to test or demonstrate waste solvent segregation, recycling, and reclamation alternatives should be established at a selected Army installation.

6. The economics of recycling solvents should be studied.

7. A solvents substitution and minimization program should be investigated.

8. Solvent-to-solvent substitution options should be made available to installations.

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APPENDIX A:

FEDERAL SUPPLY CLASSES CONTAINING ITEMS THAT MAY BE TOXIC OR HAZARDOUS

3439 - Miscellaneous welding, soldering and brazing supplies and accessories; fluxes; solders; brazing alloys, welding rods, electrodes nongraphic

3620 - Rubber and plastics working machinery only concerned with plastic extrusion or molding operations

3540 - Wrapping and packaging machinery only concerned with foam-in-place type operations

5640 - Thermal insulation material--asbestos only

6505 - Drugs, biologicals, and official reagents

6810 - Chemicals

6820 - Dyes

6830 - Gases: compressed and liquified

6840 - Pest control agents and disinfectants

6850 - Miscellaneous chemical specialties

7930 - Cleaning materials

7970 - Cleaning and polishing compounds and preparations

8010 - Paints, dopes, varnishes, and related products except water base

8030 - Preservative and sealing compounds

8040 - Adhesives

9110 - Fuels, solid

9130 - Liquid propellants and fuels, petroleum base

9135 - Liquid propellant fuels and oxidizers, chemical base

9140 - Fuel oils

9150 - Oils and greases: cutting, lubricating and hydraulic

9160 - Miscellaneous waxes, oils and fats

9390 - Miscellaneous fabricated non-metallic materials (asbestos only)

9620 - Minerals, natural and synthetic (asbestos, silica, quartz)

APPENDIX B:

ECONOMIC ANALYSIS FOR SOLVENT MANAGEMENT OPTIONS

This appendix will help users compare life-cycle cost (LCC) analyses for each solvent management alternative given in Chapter 3. The LCC analysis for each option is developed for a 10-year project life, because it is anticipated that most of the equipment used will last 10 years. To provide comparability, each LCC analysis must be completed for the full 10 years. The complete anticipated expenses for each year should be calculated. Some items, such as investment, will always be blank for some options and blank only after the first year for others. This will be taken into account when analyzing the total LCC.

When determining which option or combination of options to choose, it is important to consider the complete LCC for each one. This appendix is organized so that each option is separate and can be analyzed systematically, incorporating the most important LCC elements.

The information required to do an LCC analysis is installation-specific and cannot be generalized. However, some typical cost ranges and other pertinent considerations are explained for each option.

Before considering any option, an installation must first know fairly well how much solvent is required to accomplish its mission. The installation's solvent demand must be known in order to compute each potential LCC analysis. The amount of solvent used in the past is usually a pretty good indicator of the overall requirements; assuming that everything will remain the same and modifications such as mission changes or process changes are not contemplated, this amount can be used for the LCC analysis.

Another important factor is that the LCC analyses are designed for segregated solvents. Mixed solvents have different boiling points and cannot usually be processed together when the recycling options are considered. Halogenated solvents should not be burned in boilers, so their presence in solvent mixtures being recovered for energy makes burning an undesirable option.

Vapor pressure and losses affect the accuracy of LCC analyses. For example, the solvent PD680 (Stoddard dry cleaning) has a low vapor pressure and low volatility. It is one of the most commonly used solvents and does not evaporate readily. However, trichloroethylene, which is vaporized when used in a vapor degreaser, has a high vapor pressure, so substantial evaporation losses occur. Therefore, losses from vapor pressure and normal usage must be accounted for to estimate the amount of used solvent available for disposal and, ultimately, to determine the amount of solvent that must be purchased after recycling.

Each solvent management option depends on both complete segregation of solvents and sound management principles. In other words, contamination of spent solvent with foreign materials such as cigarette butts, scrap metal, PCBs, water, and other unknown materials lessens the value of the spent solvent and greatly increases the cost of its disposal. If solvents become

contaminated with various unknown substances or become mixed with undesirable materials, costly analyses are required before any of the disposal options can be implemented. Therefore, it is very important to segregate as well as to maintain the constituency of spent solvents.

Life-Cycle Cost Analysis for Recycle On-Post--Option 1

Recycling solvents on post almost always means purchasing distillation equipment. This equipment is readily available, and its size and configuration depend on the amounts and types of solvents to be processed. Some of the solvents with boiling points above 300°F will require vacuum systems to make the process more efficient. Most of the smaller processes (less than 100 gal/day) operate in the batch mode. The smaller stills use electricity for energy, and the larger ones use steam.

The cost of new solvent required as make-up solvent must be determined. Typically, for PD680 solvent use, about 30 percent of the solvent is lost during use. Another 5 to 10 percent is lost during distillation. The total amount of solvent that must be replaced amounts to about 35 to 40 percent of the total requirement. Solvents with different vapor pressures and different uses will have a different loss rate. Figure B1 is a chart for calculating the LCC for Option 1.

Life-Cycle Cost Analysis for Recycle Off Post--Option 2

Off-post recycling of solvents usually requires that the waste solvents be segregated and free of unusual contaminants. If contamination is a problem, the contractor will usually charge a higher price and require costly analyses to determine the nature of the contaminants.

Storage and transportation are usually significant for this disposal option. Most contractors want to pick up a full truckload of solvent, so the installation must therefore be able to store 4000 to 6000 gal of waste solvents. Containers such as 55-gal drums are commonly used for storing waste solvent and for picking up re-refined solvent from the contractor. The cost of supplying and/or reconditioning storage containers should be determined when considering this option. For example, one contractor supplies reconditioned drums to customers at $15 per drum. Contractors will also charge a transportation fee to pick up a customer's waste solvent and deliver re-refined solvent based on distance and ease of transferring the solvent from the customer's container to the truck. Figure B2 is a chart for calculating the LCC for Option 2.

Life Cycle Cost Analysis for Disposal by Contract--Option 3

Disposal by Contract

The installation can contract for disposal of used solvents, usually by incineration or landfilling—environmentally acceptable methods for disposing of the waste materials. However, disposal costs can be substantial.

Year	(A) Cost of New Solvent	(B) Investment	(C) Recurring Cost	(D) Total Annual Cost	(E) 10% Present Value Factor	(F) Present Value
1					.954	
2					.867	
3					.788	
4					.717	
5					.652	
6					.592	
7					.538	
8					.489	
9					.445	
10					.405	
					(G) LCC = total	

(A) Cost of new solvent that must be purchased each year due to losses during use (35 to 40 percent of the total solvent requirement is lost and must be purchased as new solvent).

(B) Cost of the equipment needed for distilling used solvent plus installation cost.

(C) Recurring costs include:

- -- labor required to tend the still and make minor repairs.
- -- power required to operate the still.
- -- materials such as disposable bags for the residue, etc.
- -- maintenance on the still such as replacing the heating element.
- -- disposal cost of the sludge disposal through a hazardous waste disposal contractor.

(D) The total cost for each year, A+B+C.

(E) Present-value factors, using a 10 percent discount rate (taken from standard economic tables).

(F) Present value for each year of projected operation (D)x(E).

(G) LCC = the sum of all annual present-value costs for the life of the project.

Figure B1. Chart for calculating LCC for recycle on-post--Option 1.

Year	(A) Cost of New Solvent	(B) Investment	(C) Recurring Cost	(D) Total Annual Cost	(E) 10% Present Value Factor	(F) Present Value
1					.954	
2					.867	
3					.788	
4					.717	
5					.652	
6					.592	
7					.538	
8					.489	
9					.445	
10					.405	
					(G) LCC = total	

(A) Cost of new solvent that must be purchased each year due to losses during use and the refining processes. (30 percent of new solvent is typical during use, and 5 to 10 percent is lost during refining; therefore, 35 to 40 percent of the total solvent requirement must be new solvent.)

(B) Cost of equipment used for storage and storage costs.

(C) Recurring costs include refining cost, labor, and transportation.

(D) The total cost for each year, A+B+C.

(E) Present-value factors using a 10 percent discount rate (taken from standard economic tables).

(F) Present value is (D)x(E).

(G) LCC = the sum of all annual present-value costs for the life of the project.

Figure B2. Chart for calculating LCC for recycle off-post--Option 2.

Thus, contracting may not be the most economically attractive alternative if the material has some reclamation or sale value. Separation of solvents for disposal is highly desirable, because compared to segregated wastes, mixed wastes frequently are more costly to dispose of.

Some examples of used solvent disposal costs to Defense Property Disposal Service (DPDS) are:

PD680--$1.93 per gal

Trichloroethylene--$0.67 to $0.95 per gal

Dry-cleaning solvent--$1.00 per gal.

Sale

Some used solvents may have sales value. Usually, the material is turned in to DPDS and handled through their sales cycle. This can produce income for the installation and promote recycling. Alternatively, the installation itself could sell the material if there is an available market. The sales potential is much greater for segregated solvents than for mixed wastes.

For some materials, take-back by the manufacturer or supplier, usually for reprocessing, is a possibility. The user either receives a credit or pays a small fee for this disposition. This option is particularly attractive for materials which are originally mixtures and are difficult or impossible for the user to reconstitute for reuse. Figure B3 is a chart for calculating the LCC for Option 3.

Life-Cycle Cost Analysis for Disposal by Service Contract--Option 4

Some solvents may be provided on a contractual basis with new (or recycled) solvent provided as needed and the used solvent removed from the installation. This eliminates the need for the user to dispose of the waste solvent. Usually, the waste solvent is reclaimed and returned to the users, which reduces the cost of the solvent service. The fee is based on the volume of solvent used.

For example, one company operates a service for solvents used for cleaning old parts. The service includes either: (1) the rental and the cleaning and servicing of a parts-cleaning machine(s), and (2) cleaning the customer-owned machines. Frequency of solvent replacement depends on the customer's needs. Customer-owned machine service providing mineral spirits (PD680) for parts cleaning costs about $2.14 per gal, with a minimum of 30 to 40 gal per delivery.

A carburetor cleaner (mixed solvent) is provided for about $9 per gal for a customer-owned machine, or 6 gal of solvent with a parts washer and agitating machine are provided for $52.50 per month. Figure B4 is a chart for calculating the LCC for Option 4.

Year	(A) Cost of New Solvent	(B) Investment	(C) Recurring Cost	(D) Total Annual Cost	(E) 10% Present Value Factor	(F) Present Value
1					.954	
2					.867	
3					.788	
4					.717	
5					.652	
6					.592	
7					.538	
8					.489	
9					.445	
10					.405	
					(G) LCC = total	

(A) Cost of new solvent that must be purchased each year. Since no solvents are recycled, it is assumed that this will be the total solvent requirement cost.

(B) Costs for items such as storage requirements (e.g., buildings or containers).

(C) Recurring costs would be contract charges for the disposal of the waste solvent (this could be positive factor, i.e., if the waste solvent can be sold), transportation, and labor (70 percent of the original solvent volume must be disposed of by contract).

(D) The total cost for each year, A+B+C.

(E) 10 percent value factor (from standard economic tables).

(F) Present value = (D) x (E).

(G) LCC = the sum of all annual present-value costs for the life of the project.

Figure B3. Chart for calculating LCC for disposal by contract--Option 3.

Year	(A) Cost of New Solvent	(B) Investment	(C) Recurring Cost	(D) Total Annual Cost	(E) 10% Present Value Factor	(F) Present Value
1					.954	
2					.867	
3					.788	
4					.717	
5					.652	
6					.592	
7					.538	
8					.489	
9					.445	
10					.405	
					(G) LCC = total	

(A) Cost of new solvent (NA).

(B) Investment costs (NA).

(C) Recurring cost is the cost of the contract to supply a certain amount of solvent for 1 year.

(D) Total A+B+C.

(E) Present-value factor (from standard economic tables).

(F) Present value = (D) x (E).

(G) LCC = the sum of all annual present-value costs for the life of the project.

Figure B4. Chart for calculating LCC for disposal by service contract--Option 4.

Life Cycle Cost Analysis for Disposal by Burning in Industrial Boiler--Option 5

Disposal by mixing solvents with waste crankcase oil and burning the mixture in boilers is practical at several Army installations. This method of disposal/heat recovery is currently acceptable as a disposal method. However, this is reason to believe that the RCRA reauthorization bill will declare all used oil as a hazardous waste. The proposed bill also forbids used oil to be mixed with other hazardous wates such as solvents. Therefore, before this option is chosen, State and Federal regulations pertaining to air pollution and hazardous waste disposal should be investigated thoroughly. This option is considered as recycling for the purpose of energy recovery as long as the solvent contains at least as much heating value/energy as a low-energy commercial fuel such as wood. Figure B5 is a chart for calculating the LCC for Option 5.

Year	(A) Cost of New Solvent	(B) Heating Value	(C) Investment	(D) Recurring Cost	(E) Total Annual Cost	(F) 10% Present Value Factor	Present Value
1						.954	
2						.867	
3						.788	
4						.717	
5						.652	
6						.592	
7						.538	
8						.489	
9						.445	
10						.405	
						(G) LCC = total	

(A) The cost of the new solvent required per year.

(B) The heating value of the solvent burned (Btu/gal solvent) x gal used/yr x cost ($)/Btu of the design fuel not used = cost/year. (This value would be entered as a negative number which, reduces the gross solvent cost.)

(C) Capital investment for storag, treatment, and burning equipment.

(D) Recurring costs include labor for treatment and processing solvent prior to combustion, as well as residue disposal and extra boiler maintenance.

(E) (A) + (B) + (C) + (D).

(F) 10 percent value factors (from standard economic tables).

(G) (E) x (F).

(H) LCC = the sum of all annual present-value costs for the life of the project.

Figure B5. Chart for calculating LCC for disposal by burning in industrial boiler--Option 5.

APPENDIX C:

SOLVENT RECOVERY EQUIPMENT MANUFACTURERS AND RECLAIMERS

DISTILLATION/FRACTIONATION PROCESSES

Artison Industries, Inc.
73 Pond Street
Waltham, MA 02254
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Ecolaire Heat Transfer Company
1550 Lehigh Drive
Easton, PA 18042
(215) 250-1000

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Erie, PA 16501
(814) 455-4478

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Olympia Fields, IL 60461
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Westport, MA 02790
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(201) 747-8130

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Lutherville, MD 21093
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Douglasville, GA 30134
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Chemical Recovery Systems, Inc.
36345 Van Born Road
Romulus, MI 48174
(313) 326-3100

Conservation Chemical Co.
5201-T Johnson Drive
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Marisol, Inc.
123 Factory Lane
Middlesex, NJ 08846
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Organic Chemicals, Inc.
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APPENDIX D:

SOLVENT DEMAND ANALYSIS

Total Amount (Gal)

NOMENCLATURE	CONUS	DARCOM	ARNG	FORSCOM	TRADOC	HEALTH SERVICES COMMAND	ARMY COMMUNICATIONS COMMAND	OTHER COMMANDS
Acetone	23,093	11,960	3,634	1258	879	2152	45	3143
Alcohol, Butyl	--	--	--	--	--	--	--	4
Alcohol, n-Butyl	104	49	19	23	7	-	15	--
Alcohol, Denatured	27,039	4,630	4,991	5,741	4596	164	180	205,667
Alcohol, Ethyl	431	10	49	89	5	5	--	250
Alcohol, Isobutyl	4	--	--	0.4	--	36	--	--
Alcohol, Isopentyl	1	--	--	--	--	1	--	1
Alcohol, Isopropyl	5833	1,002	1,306	1115	888	90	278	965
n-Amyl Acetate	410	5	167	134	31	1	1	72
n-Butyl Acetate	1	--	1	--	--	--	--	--
Benzene	45	--	24	14	5	--	--	2
Calibrating Fluid	4730	4455	--	--	55	--	--	220
Carbon Tetrachloride	46	--	45	--	--	--	--	1
Carbon Removing Compound	119,131	96,493	3883	3460	1015	--	5	1510
Chloroform	338	48	--	52	1	236	--	1
Cleaning Compound, Rifle Bore	16,933	197	2321	6605	9126	3	24	652
Cleaning Compound Solvent	204,201	37,146	16,088	--	28,635	--	--	--
Cleaning Compounds	--	--	--	95,097	--	100	546	23,818
Cleaning and Lubricating Solvent	--	--	--	17	5	--	--	50
Cleanup Solvent	107	461	2095	--	--	--	--	--
Coating Compounds	48 lb	--	--	--	48 lb	--	--	--
Corrosion Removing Compound	85,105	55,622	449	1203	1155	--	--	161
Corrosion Removing Compound (lb)	--	282,000	1200	--	--	--	--	--
Cyclohexanone	--	--	--	--	--	--	--	--

Total Amount (Gal) (Con't)

NOMENCLATURE	CONUS	DARCOM	ARNG	FORSCOM	TRADOC	HEALTH SERVICES COMMAND	ARMY COMMUNICATIONS COMMAND	OTHER COMMANDS
Dibutyl Phthalate	--	--	--	--	--	--	--	--
p-Dichlorobenzene	705 lb	25 lb	624 lb	15 lb	41 lb	--	--	--
Dichloromethane	1694	85	1221	160	71	--	--	100,148
Dry Cleaning Solvent	--	--	--	--	11	--	--	--
Dry Cleaning Solvent, Type I	--	--	--	--	--	--	--	--
Dry Cleaning Solvent, Type II	--	--	--	--	--	2750	--	--
Ethyl Ether	--	--	5 lbs	16	1	258	--	0.17
Ethly Ether, Anhydrous	276	1	--	--	--	--	--	--
Ethylene Chloride	2	--	--	--	2	--	--	--
Ethlyene Glycol	2539	6	12	37	1262	50	525	407
Ethylene Glycol, Monobutyl	1001	381	211	277	65	--	--	67
Fluid Deletion	251	33	6	72	50	--	--	90
Furniture Polish	370	35	2	218.5	91	--	6	48
n-Heptane	15	--	--	15	--	--	--	--
n-Hexane	--	--	--	--	--	--	--	--
Inhibitor, Icing Fuel	76,786	2135	2266	61,660	7690	--	--	3035
Insulators	90	90	--	--	--	--	--	--
Lithographic Solvent	9	--	--	2	--	--	--	7
Methanol	14,459	272	1774	4685	2086	1199	--	4358
Methyl Ethyl ketone (MEK)	24,224	8886	4844	3448	3782	--	92	3124
Methyl Ethyl Ketone Peroxide	38 lb	--	--	--	30 lb	--	--	8
Methyl Isobutyl Ketone (MIBK)	294	--	3	153	7	--	--	131
Naptha, Aliphatic	140,607	3236	51,280	56,907	12,584	--	--	1111
Naptha, Aromatic	64,331	342	93	154	7852	--	--	65,986

Total Amount (Gal) (Cont'd)

NOMENCLATURE	CONUS	DARCOM	ARNG	FORSCOM	TRADOC	HEALTH SERVICES COMMAND	ARMY COMMUNICATIONS COMMAND	OTHER COMMANDS
Naptha, Aromatic, Type II	--	--	--	--	--	--	444	--
Napthalene	3200 lb	--	1344 lb	1087 lb	761 lb	--	--	18
p-Naphthol Benzein	0.125 lb	--	--	0.1 lb	--	--	--	--
Paint Remover	--	--	--	--	--	--	--	--
Petroleum Ether	953	475	--	305	304	--	--	54
Phenol	<1	--	--	--	--	--	--	0.25
Phosphate Coating Liquid	4125	4050	15	--	60	--	--	--
Tetrachloroethylene	2124	--	125	265	1340	--	55	330
1,1,1-Trichloroethane	1,041,437	1,005,251	2140	10,835	3146	3	--	1995
Trichloroethylene	104,084	99,077	842	887	1205	--	--	2081
Toluene	53,167	47,098	849	2720	869	--	8	201
Toluene -- Methyl Isobutyl Ketone	573	86	145	235	30	--	--	70
Xylene	52,348	18,745	6153	12,303	1839	3428	50	9832

Outside Continental U.S.

Total Amount (Gal)

SUMMARY	GERMANY	ITALY	JAPAN	S.KOREA	PANAMA	DUTCH WEST INDIES	TURKEY	ENGLAND	HAWAII	ALASKA	OTHER
17,058	746	356	545	7277	166	--	10	--	304	371	186
--	--	--	--	--	--	--	--	--	--	--	--
73	67	--	--	--	2	--	--	--	4	--	--
61,733	41,612	383	11	15,769	1510	<1	12	26	634	1766	11
66	20	--	--	16	--	--	30	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
2	<1	--	--	--	--	--	--	--	2	--	--
6142	4205	566	12	533.5	4	51	5	--	55	771	<1
200	170	3	2	11	1	--	<1	--	4	7	3
--	--	--	--	--	--	--	--	--	--	--	--
50	15	--	--	14	--	3	--	--	12	1	5
--	--	--	--	--	--	--	--	--	--	--	--
30	30	--	--	--	--	--	--	--	--	--	--
2870	1840	15	--	200	15	135	5	--	275	360	25
37	1	--	--	--	--	--	--	--	6	--	30
8649	5317	45	2	1978	314	280	14	--	401	286	13
297,172	21,516	1442	3698	256,331	2475	865	313	56	5450	4591	199
19	10	--	5	3	--	--	2	--	--	3	<1
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
5876	5561	--	12	64	134	3	--	15	86	1	--
--	--	--	--	--	--	--	--	--	--	--	--
<1	--	<1	--	--	--	--	--	--	--	--	--

Outside Continental U.S.

Total Amount (Gal) (Cont'd)

SUMMARY	GERMANY	ITALY	JAPAN	S.KOREA	PANAMA	DUTCH WEST INDIES	TURKEY	ENGLAND	HAWAII	ALASKA	OTHER
<1	--	--	1	--	--	--	--	--	--	--	--
7296 lb	--	122 lb	--	--	7030 lb	--	--	--	--	--	144
101	60	--	--	--	--	--	10	--	6	25	--
--	--	--	--	--	--	--	17	--	--	--	104
--	--	4798	--	--	--	--	--	--	--	--	--
--	--	2300	895	--	--	330	330	--	--	--	30
--	<1	--	30	2	6	--	--	37	40	--	1
362	--	--	--	--	--	--	--	--	--	--	6
1	--	--	--	11	--	--	--	--	--	--	--
2617	1348	12	440	417	330	--	--	--	70	--	--
241	130	2	--	--	--	--	--	--	105	2	2
--	--	--	--	--	--	--	--	--	--	--	--
12	12	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
6	2	--	4	--	--	--	--	--	--	--	--
22,538	12,925	--	--	4290	--	--	440	--	515	1618	2750
8	--	--	2	--	--	--	--	4	1	1	--
28	13	--	--	--	--	--	--	--	15	--	--
19,558	14,460	240	1	2815	8	--	2	--	505	1495	26
8333	3419	199	69	3097	389	85	--	45	611	335	84
2 lb	--	--	--	--	--	--	--	2 lb	--	--	--
122	48	--	--	--	--	--	--	--	68	6	--
239,691	105,890	--	5282	94,918	470	3069	--	690	19,962	3784	367

Outside Continental U.S.

Total Amount (Gal) (Cont'd)

SUMMARY	GERMANY	ITALY	JAPAN	S.KOREA	PANAMA	DUTCH WEST INDIES	TURKEY	ENGLAND	HAWAII	ALASKA	OTHER
416,469	302,990	--	--	85,630	1930	--	--	--	14,694	7670	--
--	--	--	--	--	--	--	--	--	--	--	--
500 lb	32 lb	100 lb	10 lb	--	124 lb	125 lb	--	10 lb	87 lb	--	12 lb
--	--	--	--	--	--	--	--	--	--	--	--
55	55	--	--	--	--	--	--	--	--	--	--
269	121	--	60	70	--	--	--	--	--	18	--
1 lb	1 lb	--	--	--	--	--	--	--	--	--	--
990	990	--	--	--	--	--	--	--	--	--	--
17,415	11,955	10	1595	2860	55	330	385	--	5	220	--
24,819	22,851	90	2	1239	1	5	169	--	72	334	32
13,349	10,016	415	440	1530	--	--	--	220	385	343	--
16,873	11,198	772	--	1231	7	2	25	--	133	69	22
208	54	--	--	1	--	--	105	--	141	25	--
12,841	11,175	190	100	1556	56	445	--	100	2467	202	15

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